MonsterMoto
“JackBot”

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Team Leader: Phillip A. Yeager
Email address: pyeager@monstermoto.com

Mailing address:
Phillip A. Yeager
11300 W. Parmer Lane, #1364
Cedar Park, TX 78613
Phone: (512) 300-7445

ABSTRACT

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1. Vehicle Description

1.1 Base Vehicle Description

The JackBot is based on a 2004 Kawasaki KFX700 two wheel drive ATV. The KFX700 is powered by a liquid-cooled, 697cc, four-stroke, 90-degree V-twin matched to a performance-tuned continuously variable automatic transmission. The KFX700 features a shaft drive, powerful dual front disc brakes and a sealed, oil-bathed, multi-disc rear brake system. The KFX700 also incorporates first mass-produced ATV chassis with a racing-inspired single lower front frame tube – the design preferred by cross-country ATV racers. Rear suspension duties are handled by a motocross-inspired swingarm with a piggy-back reservoir shock.

Photo - 2004 Kawasaki KFX700 ATV

1.2 Vehicle Modifications

The base KFX700 vehicle has been modified to meet the specific needs of autonomous desert operation.

1.2.1 Electrical Power

To satisfy the power demands of JackBot's sensors, computers and actuators, the OEM 12-volt generator is augmented with an additional 65 amp, 24 volt alternator and high capacity batteries.

1.2.2 Suspension and Running Gear

The wheel track of the OEM vehicle has been extended by 15 inches to provide lateral stability and also to facilitate negotiation of desert "2-track" dirt roads. The increased width is accomplished with Herrmann Racing's extended A-arms and DuraBlue's oversized rear axle. To improve ground clearance and traction, 27 inch desert radial tires and heavy duty steel rims replace the OEM tires and wheels. The suspension was tuned by Full Circle Cycle of Austin, Texas to better respond to the desert terrain. Finally, the underside of the chassis is protected with thick aluminum skid plates.

Photo - KFX700 With Modifications for Autonomous Operation

1.2.3 Aluminum Body

Attached to JackBot's chassis frame is a stressed skin aluminum body which houses the batteries, computer and control electronics. The central portion of this aluminum body is shock mounted and weather sealed to protect sensitive components from damage. The top of the aluminum body doubles as an antenna and sensor mast.

1.2.4 Actuators

Steering control is achieved with a large servomotor coupled to the OEM steering column and powered by a Roboteq programmable motor control center. Throttle and brake control is performed by small servos coupled to the OEM control cables. A separate, fail safe parking brake is driven directly by the Emergency Stop circuit.

2. Autonomous Operations

2.1 Processing

2.1.1 Computing Systems

The JackBot computing system is a based on a 3.2 GHz Pentium 4 desktop motherboard running the Windows XP Operating System. JackBot's control software was developed in C and C++ specifically for this application using industry standard development tools.

2.1.2 Block Diagram of Processing Architecture

2.2 Localization

2.2.1 GPS and Internal Navigation Systems

A Crossbow Navigation Attitude Heading Reference System (NAHRS) module is the main navigation and guidance application. The Crossbow NAHRS blends GPS, magnetometer and accelerometer measurements into an Extended Kalman Filter (EKF) algorithm. The EKF update responds to the relative health and status of the associated sensors. Magnetometers provide heading measurement for the EKF.

A second module forms a wrapper around this system and provides the master navigation through custom filtering of the inputs. This system augments the Crossbow navigation solution with input from a decimeter accurate Novatel GPS receiver with Omnistar capability. The master navigation filter under certain situations also employs odometry data from the wheels.

When the GPS signal is available the Crossbow acts as a NAHRS.
Hardware and software have been designed to minimize the impact of temporary failed components. However, limited redundancy in components means that permanent outages of sensors will have a detrimental effect on JackBot's performance.

A two dimensional terrain mapping module is supported with the statistical analysis of data gathered from the lasers.

2.3 Sensing

2.3.1 Location and Mounting of Vehicle Sensors

Three to four SICK LMS 291 LIDAR units are deployed at various fixed locations and orientations on JackBot. The LIDAR systems are forward looking, each with a 90 degree fan angle and include protective visors.

2.3.2 Internal Sensing and Architecture for Vehicle State Determination

Encoded optical information integrated with data from accelerometer and potentiometer sensors along with, current and voltage measurements provide the basis for vehicle state sensing.

2.3.3 Sensing-to-Actuation System to Develop Vehicle Response

Recent sensor data are evaluated and mathematically weighted and evaluated to calculate appropriate vehicle response under ever-changing conditions. The behavior based algorithms include local obstacle avoidance algorithms which attempt to eliminate directive solutions which would result in JackBot from both halting (without restarting) and from straying off-course. JackBot slows down when it senses imminent obstacles. The software develops and analyzes various path trajectories and directs JackBot response to minimize undesirable outcomes (including loss of path progression to the next way-point).

2.4 Vehicle Control

2.4.1 Management of Autonomous Operation Contingencies

It is anticipated that behavior based response algorithms and various estimation routines will ensure obstacle avoidance and the minimization of operational contingencies.

2.4.2 Special On-Course Corrections and Operation

JackBot responds in real time to data provided through PID control loops. Specifically, PID control loops drive both front and rear brakes as well as steering. An auxiliary fail safe brake is driven by an E-Stop circuit. Wheel speed sensors are used to control JackBot’s antilock brakes.

2.4.3 Method for Integration of Navigation and Sensing Information

Tightly coupled sensor and GPS data along with behavior scenarios are the basis of the

JackBot navigation system. These data are analyzed within the navigation system through the use of a Kalman filter.

2.4.4 Control of Vehicle When Not in Autonomous Mode

JackBot software employs behavior based navigation methods to determine motion recommendations for the unit. The behavior based scenarios utilize a two dimensional cell-based terrain map. Mathematical analysis and transformation of sensor and GPS data provide the basis for obstacle negotiation decisions.

2.5 System Tests

2.5.1 Testing Strategy to Ensure Vehicle Readiness for DGC

JackBot testing included both physical and software-only simulation runs. Initial physical testing was conducted on a simple obstacle course. More advanced field testing was done in Texas field terrain. Software-only testing evaluated individual module behavior as well as integration testing. Scenarios were developed to mimic the loss of data as well as terrain obstacles. Multiple simulation runs, particularly obstacle avoidance scenarios, were executed prior to field testing. Both the hardware and software were modified to attempt to remedy shortcomings identified during testing.

2.5.2 Test Results and Key Challenges

Test results yielded encouraging information, but procuring equipment, skilled labor, and sufficient funding also provided formidable challenges for the team.